FINITE AND INFINTE ELEMENT METHODS FOR UNDEX SIMULATIONS

J. Cipolla and J. Nagtegaal[a]

[a]ABAQUS, Inc.
1080 Main St.
Pawtucket, RI, 02860-4847
Jeffrey.Cipolla@abaqus.com
Joop.Nagtegaal@abaqus.com

The acronym "UNDEX" refers to simulations of underwater explosion effects on submerged and floating structures. Earlier methodologies for analyzing the coupled structural-fluid system have been supplanted by finite element methods, new absorbing boundary conditions, and new infinite elements. For large problems, gains in accuracy and computational efficiency are significant.

The complexity of UNDEX phenomena makes computational methods necessary. Until recently, the most satisfactory method for modeling the exterior fluid has been the "Doubly Asymptotic Approximation" (DAA) of Geers [1]. Here, the scalar wave equation on the external fluid field is transformed to an integral equation, which is approximated in the Laplace domain. This formulation uses matrices that are fully populated in an implicit time-stepping scheme. Efficient for many smaller problems, this methodology becomes cost-prohibitive for the size of systems of current interest.

Several computational methods have been integrated within ABAQUS to solve large problems with greater accuracy than previous methods. Use of the finite element method in the exterior fluid domain allows the DAA to be relaxed. The accurate modeling of the radiation condition has been achieved through the use of first-order absorbing boundary conditions, and infinite elements of a newly modified formulation. The first-order conditions are based on several well-known families for wave propagation. Simple convex-surface approximations ([2], [3]) are generalized for transient analysis with fluids that may have mechanical losses (damping). A first order condition for plane waves at arbitrary incident angles has been developed from [4]. These conditions are spatially and temporally local, imposing virtually no marginal computational cost on a finite element analysis. Development of efficient higher-order methods at the exterior boundary has been accomplished through a modification of the formulation of Astley et al [5]. The inertia formulation has been modified to ensure stability, and an operator split, which preserves the high order approximation of the element, is employed for compatibility with an explicit time integration scheme.

These methods, in combination, enable UNDEX problems to be solved using finite element methods exclusively, without resort to the DAA approximation and its fully populated matrices. Examples are shown of the resulting accuracy, and computational time comparisons are also shown.

References

[1] T. Geers, "Doubly Asymptotic Approximations for Transient Motions of Submerged Structures," *Journal of the Acoustical Society of America*, v. 64, n. 5, p. 1500-1508, 1978.
[2] Bayliss, A., M. Gunzberger, and E. Turkel, "Boundary Conditions for the Numerical Solution of Elliptic Equations in Exterior Regions," *SIAM Journal of Applied Mathematics*, vol.42, no.2, pp. 430–451, 1982.
[3] Grote, M., and J. Keller, "On Nonreflecting Boundary Conditions," *Journal of Computational Physics*, vol.122, pp. 231–243, 1995.
[4] Sandler, I. S., "A New Computational Procedure for Wave Propagation Problems and a New Procedure for Non-Reflection Boundaries," *Computer Methods in Applied Mechanics and Engineering*, vol.164, pp. 223–233, 1998.
[5] Astley, R. J., G. J. Macaulay, and J. P. Coyette, "Mapped Wave Envelope Elements for Acoustical Radiation and Scattering," *Journal of Sound and Vibration*, vol.170, pp. 97–118, 1994.